CALIFORNIA DIVISION OF MINES AND GEOLOGY

Fault Evaluation Report FER-13

December 2, 1976

1. Name of fault: Ventura Fault (also known as the Ventura Foothills fault).

2. Location of fault: Ventura and Saticoy 7.5' quadrangles, Ventura County (this fault passes through the City of Ventura as well).

3. Reason for evaluation: Part of 10-year program; this fault is zoned in the Ventura County Seismic and Safety Element (Nichols, 1974).

4. References:


a) Celwick, B.A., June 1975, Geologic/Fault Investigation, General Hospital Complex Planning Study, Project 9674: unpublished report by Ventura County Public Works Agency.

b) Fugro, February 11, 1974, Geologic-Seismic Investigation, Proposed Government Center, County of Ventura, California, Project no. 73-091-EG: unpublished consulting report on file with Ventura County public Works Agency.

c) Gonzales, J., November 18, 1976, oral communication.

d) Jennings, C.W., 1975 Fault Map of California with locations of volcanoes, thermal springs and thermal wells: California Division of Mines and Geology, California Geologic Data Map Series, Map no. 1, scale 1:750,000.

e) Nichols, D.R., 1974, Surface faulting in Seismic and Safety Elements of the Resources Plan and Program: Ventura County Planning Department, section II, p. 1-35, pl. 1.

f) Ogle, B.A., and Hacker, R.N., 1969, Cross section coastal area Ventura County in Geology and Oil fields of coastal areas Ventura and Los Angeles basins, California: Pacific Sections American Association of Petroleum Geologists, Society of Exploration Geophysicists and Society of Economic Paleontologists and Mineralogists 44th Annual Meeting field trip guidebook, scale 1:48,000.

g) Putnam, W.C., 1942, Geomorphology of the Ventura region, California: Geological Society of America Bulletin, v. 53, p. 691-754, 5 plates, 11 figures.

h) Quick, G.L., 1974, Preliminary microzonation for surface faulting in Ventura, California area in Geology, seismicity, and environmental impact: Association of Engineering Geologists, Special Publication, p. 257-262. Note: Basically contains only information obtained from others; no new data. Not discussed herein.

i) Sarna-Wojcicki, A.M., Williams, K.M., and Yerkes, R.F., (1976), Geology of the Ventura fault, Ventura County, California: unpublished USGS report (to be published soon), map scale 1:600. (Note: Now published as U.S. Geological Survey, Miscellaneous Field Studies Map, MF-781.)

j) Turner, John, November 18, 1976, oral communication.

k) Weber, F.H., Jr., Cleveland, G.B., Kahle, J.E., Kiessling, E.F., Miller, R.V., Mills, M.F., Morton, D.M., and Cilweck, B.A., 1973, Geology and mineral resources study of southern Ventura County, California: California Division of Mines and Geology, Preliminary Report 14, 102 p., 5 pl., 9 figures; map scale 1:48,000.

l) Weber, F.H., Jr., Kiessling, E.W., Sprotte, E.C., Johnson, J.A., Sherburne, R.W., and Cleveland, G.B., 1975 (Preliminary draft

FER 13 Figure 1 (From Nichols, 1974).


HAZARDS PLATE 1

# SEISMIC & SAFETY ELEMENTS
of the
# RESOURCES PLAN & PROGRAM

ventura county planning department  october 1974

of 2/27/76), Seismic hazards study of Ventura County, California: California Division of Mines and Geology, Open File Report 76-5LA, 396 p., 9 pl., map scale 1:48,000.

m) Ziony, J.I., Wentworth, C.M., Buchanan-Banks, J.M., and Wagner, H.C., 1974, Preliminary map showing recency of faulting in coastal southern California: U.S. Geological Survey, Miscellaneous Field Studies Map MF-585, 15 p., map scale 1:250,000, 3 pl.

5. Summary of available data:

Some confusion exists over the proper name of the Ventura fault. The name "Ventura Foothills fault" was first used by Quick (1974) and Nichols (1974).

Most recently, Weber, et al. (1975) and Sarna-Wojcicki, et al., (1976), refer to the fault as the "Ventura fault." Sarna-Wojcicki et al. is the most detailed work along the fault, and will probably be the major reference of those who zone the fault (if it is zoned) and those consultants who investigate the fault. Thus, the fault is referred to as the Ventura fault in this report.

The Ventura fault is zoned as a secondary fault hazard by Nichols (1974) after Weber, et al. (1973). Weber, et al. (1973) depict an (unnamed) air photo lineament, possibly a fault but not verified, along the general trend of the Ventura fault.

Jennings (1975), after Ziony, et al. (1974), shows the fault as a buried fault which cuts units Quaternary ~~in age.~~ Ziony, et al. also note three late-Quaternary faults immediately north of the Ventura Foothill fault (see stars in figure 2).

The first mention of faulting in the vicinity of the Ventura fault was made by Putnam (1942, p. 744). He noted that the terraces to the north were

disrupted by several vertical and south dipping, high-angle reverse faults. To quote Putnam, "displacement on these faults is probably the result of Recent movement on larger Pleistocene faults ...". Putnam does not locate these faults on a map.

Ogle and Hacker (1969), in a cross section, note that a 245 meter separation at the base of the Las Posas Formation (Pleistocene) was found in Tidewater Oil Company's Corehole 5 where it passed through the fault plane at a depth of 5100 feet. (It was their opinion that this fault was the Pitas Point fault.) Gonzales (personal communication, 1976), noted that similar data was obtained from at least two other coreholes.

Weber, et al. (1975) describe the fault as a north 45° to 60° dipping reverse fault with Holocene movement indicated. Weber, et al. also note the presence of several reverse faults in the terrace deposits north of the main fault.

Probably the best (most complete) report has yet to be released (Sarna-Wojcicki, et al. received in written communication from Yerkes, March 9, 1976, [released with minor changes as USGS MF-781]). Certainly the most definitive data for recent movement is presented in this report. The Harmon fan, at the eastern end of the fault as mapped, is cut by the fault. Samples from the fan deposits (location of sample site noted on plate 2) have been dated by amino-acid racimization at from 5700 to 6300 years before the present, which is during Holocene time. It appeared to the authors that younger fans have also been faulted, to a lesser degree; hence they believe that there has been recurrent movement along a fault. Further, they inferred from stratigraphic relationships that the fault segment between the Ventura River (on plate 1) and Day Road (on plate 2) has had a "relatively large rate of uplift" along it.

Sarna-Wojckcki, et al. describe the surface expression of the fault as follows:*

> "A topographic bench, bounded by a linear ramp or escarpment on its south side, can be traced from east of Prince Barranca... to approximately one km east of Harmon Barranca....a distance of about 6 1/2 km. Because extensive development has locally concealed or degraded the fault features, the investigation was supplemented by examination of aerial photography dating back to 1928, on which the features commonly are well expressed. Even the 1928 photos postdate extensive development in the City of Ventura, however, where features that once may have been present were already obscured in some places ..."
>
> "Where relatively undisturbed, the scarp has a sharply-defined toe and crest, a width of 30-100 m, a slope of as much as 30°, and a height of as much as 12 m. Where the scarp crosses young alluvial fans it locally is expressed as a single well-defined element; elsewhere it consists of a broad zone of en echelon elements ...."
>
> "Progressively older units underlie the upthrown bench from east to west: young fan deposits on the east, thence old fan deposits and nonmarine terrace deposits and marine terrace deposits or bedrock. This relation suggests that the segment of hills between the Ventura River and stream 10 ... forms a local structural high along the south limb of the Ventura Avenue anticline, perhaps due to a relatively large rate of uplift along this segment of the fault ..."
>
> "Gradients of most streams that cross the escarpment are deflected upward north of the escarpment; mismatches in altitude are as great as 25 m."

The Ventura County Public Works agency dug a trench (shown on plate 1) across the escarpment on the Ventura County Hospital grounds. Sarna-Wojcicki inspected and logged the trench, and noted the following (p. 16-20):

> "Numerous vertical or steeply dipping cracks cut the deposits in the trench [figure 3 of this FER]. Most of these cracks are filled with dark material derived from the soil at the surface, but some are partly open. Most of the cracks, when traced downward, are continuous with high-angle faults, which offset gently- to moderately-dipping alluvium (stream terrace or alluvial fan deposits containing buried paleosols). Apparent vertical dis-

*These are excerpts from the manuscript, which was published with only minor changes.

placements on these faults range from about 2 to 40 cm. On the north end of trench A-A', beyond the crest of the escarpment, apparent displacements on the faults are both up and down to the south with fault traces either vertical or steeply dipping, mainly to the south. Near the crest of the escarpment and to the south, apparent displacements are uniformly up on the south, with fault traces dipping steeply to the north [figure 3 of this FER]. The faults strike from N75E to N80W, but nearly east-west strikes are predominant."

"In addition to the trench, six bucket-auger holes were drilled on the Ventura County Hospital grounds ...."

"Sediments and soils encountered south of the escarpment are inferred to be younger than those ot the north. South of the escarpment, sediments are horizontal or gently dipping, loose, and have a weak soil profile developed at the surface. These sediments are most likely Holocene alluvial fan or stream channel deposits. Sediments and soils encountered in the trenches and auger holes at and north of the escarpment appear to be older..."

"The topographic expression of the escarpment, combined with the geometry of deformation observed in the trenches and auger holes, can be interpreted as a broad flexure of late Pleistocene deposits above a discrete bedrock fault at depth, movement on which is up on the north relative to the south block. The small graben at the crest of the escarpment probably represents a collapsed "keystone" in the center of this flexure. Though apparent displacements on faults in the trench and orientation of the escarpment suggest that chiefly vertical or high-angle reverse faulting has taken place, apparent reverse drag on many faults in the southern part of the trench [figure 3 in this FER] indicates that some component of strike-slip motion may have occurred. Other evidence for a strike-slip component includes stratigraphic discontinuities (abrupt thinning or thickening of units) across the faults, steeply-plunging folds in bedrock to the north, and the focal-plane solution for an earthquake ..."

"If the near-surface attitudes of the fractures and faults in the trenches are projected to depth, most of them intersect between 45 to 70 m below the surface, and slightly north of the crest of the escarpment. This may be the approximate depth below which the fault becomes a discrete surface. Average dip of north-dipping faults and fractures in the branches is 63°.

"Evidence of faulting is preserved at two other localities along the scarp. In Arundell Barranca .... about 60 m north of the Ventura fault, a 1 m-thick paleosol with very well-developed

"B" horizon is exposed about 6 m below the ground surface. The general slope of the units there is about 10° S; however, the paleosol is sharply flexed to about 40° S near the fault and does not reappear south of the fault."

"At another locality, where the projection of the escarpment crosses Harmon Barranca .... a buried, poorly developed soil profile is exposed along the west wall of the barranca. This soil appears to be much younger than that exposed at Arundell Barranca. This profile dips gently to the south, but more steeply than the fan surface, and appears to intersect the ground surface in the vicinity of the projected trace of the escarpment. The appearance, location and attitude of this soil are very similar to that of the soil found in auger holes 1-3 south of the escarpment on the Ventura County Hospital grounds, and they may be the same. This suggests that young alluvial fan deposits are also deformed in the vicinity of the escarpment, and that deformation is recent."

About the origin of the scarp they note:

"Many lines of evidence demonstrate that the scarp was formed by recent faulting with a large component of dip slip (up on the north):

1. It is located at the steep south flank of the Ventura Avenue anticline in a region characterized by prominent compressive deformation on east-trending axes;

2. It is directly alined with the east-trending Pitas Point fault, previously mapped for more than 30 km in the eastern Santa Barbara Channel. The Pitas Point displaces Holocene deposits and shows apparent vertical separation of about 25 m, up on the north (Greene and others, ms)*;

3. It forms a consistent structural boundary between deformed older units on the north and undeformed surficial units on the south;

4. It forms a prominent anomaly in the generalized topography of the area;

5. The gradients of most streams are sharply deflected upward on the north where they cross the scarp;

*[Now published as Green, H.G., ]976, Late Cenozoic geology of the Ventura Basin, California in Howell, D.G., ed., Aspects of the geologic history of the California continental borderland: Pacific Section, American Association of Petroleum Geologists, Miscellaneous Publication 24, p. 499-529]

6. Surficial deposits overlying the scarp are deformed by arching and displacement on small faults that penetrate upward to the surface soil [see figure 2, this FER]; progressively-steeper dips downward in the auger holes on and north of the escarpment are also consistent with an interpretation that a fault is present at depth beneath the escarpment, and that movement on the fault has occurred over a considerable span of time;

7. Well-developed buried Sangamon(?) soils that have thick oxidized B horizons are sharply flexed just north of the fault in the old fan of Arundell Barranca, ~~[stream no. 11, east edge of map sheet 2)]~~ and the Ventura County Hospital grounds;

8. The scarp forms a persistent, linear boundary between older soils, having well-developed B horizons, on the north, and younger soils lacking B horizons on the south;

9. The focal mechanism of one fairly-well located (± 5 km) earthquake, attributable to a north-dipping fault geometrically compatible with the scarp, indicates reverse- left-oblique displacement, with the reverse component dominant;

10. The scarp cannot be attributed to erosion related to present-day drainage."

About the attitude of the fault they state:

"Even though the Ventura fault is nowhere exposed [underlining added for emphasis], four lines of evidence indicate that it is a north-dipping reverse fault:

1. It forms the south boundary of one of the east-trending Transverse Ranges, in a province where such boundaries are formed by north-dipping reverse faults;

2. Ogle and Hacker (1969) published a north-south structure section that crosses the Ventura Avenue anticline aobut 5 km east of the Ventura River. The section indicates a dip of 60° N for a reverse fault equivalent to the Ventura fault;

3. One nodal plane for an earthquake attributable to the Ventura fault dips about 70° N, and the plane formed by the focus and the surface location of the scarp dips 72° N. The location of the earthquake and the focal plane solution were derived without knowledge of the Ventura fault;

4. Surficial deposits that overlie the scarp in the Ventura Hospital area are cut by many small faults; the near-surface dip of the north-dipping faults averages about 63° N in a trench across the scarp" [see figure 2, this FER].

However, by the same token, since the main fault is "nowhere exposed" and since many small faults are present in the upper block, we can expect considerable confusion among the consultants who will prepare the required reports. About displacement:

"No direct stratigraphic evidence is available as to displacement or separation on the Ventura fault. Ogle and Hacker (1969) show apparent vertical separation of about 245 m, up on the north, at the base of their "Las Posas" (Lower Pleistocene); the interpretation is based on scanty control and only permissive evidence is presented for selection of the points used on the section. Greene and others (ms) interpret acoustic sub-bottom profiles across the Pitas Point fault in the eastern Santa Barbara Channel (on strike with the Ventura fault), to indicate that: 'apparent vertical separation of about 25 m, north side up, has occurred since late Pleistocene time as shown by the displacement of (an) upper Pleistocene* erosional surface.' Projection of segments of stream profiles across the fault indicate that mismatches in altitude of 20-25 m have occurred. Where the Ventura fault scarp is relatively unmodified it has a height of about 12 m, which may be taken as the minimum vertical separation on the fault."

"Horizontal slip on the Ventura fault is indicated by the presence of local small folds, having near-vertical axes, in bedrock just north of the fault in the Ventura City area; perhaps by back-tilting on small faults exposed in the south part of trench A-A' [figure 3 in this FER]; and by the focal plane solution for an earthquake attributable to the Ventura fault, which indicates reverse- left-oblique displacement on a surface dipping about 70° NNW."

About the age of latest movement they note:

"Although the Pitas Point-Ventura fault must be considered seismically active on the basis of at least two fairly-well located earthquakes of M 3.] or larger, the surface scarp is eroded by larger streams and the stream channel deposits are not disturbed. Nor is any evidence of creep detectable along the entire trace of the scarp."

*Published version says ... "upper Pleistocene(?)"...

"The Ventura fault scarp appears to offset the surfaces of several young alluvial fans, including that of the large Harmon fan .... Though the fault can be traced almost continuously as a fault scarp or lineament over the entire distance from Prince Barranca to east of Harmon Barranca, the trace is much less pronounced where it crosses the younger fans."

"Harmon fan is most probably Holocene. It appears to be graded to approximately the present sea level and is part of the modern erosional and depositional regime. Its original constructional topography is unmodified by erosion except for the incised main channel of the barranca. Supporting evidence for a Holocene age of the fan is obtained from four amino-acid racimization dates obtained on animal bones found in a trench on the southwestern part of Harmon fan [just north of Montalvo on plate 2 of this FER]. The bones were taken from about 4.0 m below the fan surface, two of the collections represent entire skeletons of gophers taken from burrows; a third represented the entire skull of a gopher, plus loose bones. The ages range from 5700 to 6300 years b.p. (Egner and others, 1974)."

"In the intervening areas between alluvial fans, the fault scarp is more sharply expressed. In these areas, as at the Ventura County Hospital grounds, late Pleistocene terrace or alluvial fan deposits north of the fault are juxtaposed with probable Holocene alluvium south of the fault. The surface of Harmon fan appears to be offset less than that of the older late Pleistocene terrace or fan deposits, which again suggests that movement on the fault has been recurrent."

"Formation of cracks and faults in the surficial deposits (trench A-A' [figure 3 in this FER]) postdates the age of the soil exposed in the uppermost part of the trench, since the cracks are filled with soil material derived from the above. The cracks fade into the soil zone within 60 to 90 cm of the surface, and are indistinguishable from surrounding soil material. In at least one instance, however, an open crack extends all the way through the soil profile to the surface. In other instances, some cracks are unfilled or only partially filled, suggesting that they may have formed at different times." (3)

"The age of the surface soil exposed in trench A-A' [figure 3 in this FER] north of the base of the lineament at the Ventura County Hospital grounds is probably no older than Wisconsinan (10,000 to 70,000 years before present). From evidence in these trenches, some of the movement on the fault is at least as young as Wisconsinan (70,000 years) and may be younger."

On future faulting and ground deformation they state:

"for land-use purposes, it is valuable to predict in some detail the pattern of surface faulting, the amount and type of surface distortion, and the width of the zone likely to be affected...."

"The surface trace of the Ventura fault consists of a south-facing scarp 5-12 m high and 30-100 m wide; associated features north of the fault such as short, subsidiary faults and scarps, swales, and elongate depressions extend the width of the zone of deformation to about 300 m .... It is reasonable to expect that the maximum expectable earthquake postulated for the Ventura fault would be associated with transient effects and surface deformation at least as severe as those at San Fernando in 1971; such effects could affect a band at least 0.5 km wide north of and including the fault scarp."

I agree that an area 0.5 km wide could be severely affected, however, I do not feel that we necessarily should zone with such a possibility in mind. It should be realized that the site-specific investigations will be aimed at finding active faults. Most of the damage would probably occur to structures sited on the scarp. It would be impractical to avoid sites of all possible secondary fractures, if not impossible to determine which specific sites would be affected.

Disagree. EHH

The eastern end of the Ventura fault may connect with the Country Club fault (to be evaluated in a separate FER). Both faults lie along the trend of an obvious water barrier (Turner, personal communication, 1976). Turner stated that Gonzales and Quick have postulated that the western end of the Ventura fault also forms a water barrier across the mouth of the Ventura River, along the trend of the air photo lineament noted by Weber, et al. (plate 5A, 1975); however, Turner has seen the data from which Gonzales and Quick drew such a conclusion and has remained unconvinced. Turner stated that the data does not demand that a water barrier exist; however, he noted, there could conceivably be such a barrier (personal communication, 1976).

6. Interpretation of air photos: ERTS air photos flight 73-006, numbers 7637 and 7638 were viewed stereoscopically. A suggestion of a scarp east of Ventura was noted, but the resolution was so poor that no feature could be followed through the urbanized area.

Fairchild air photos (Whittier Collection) flight C-297B, numbers D1 through D11, and flight C104, numbers A1 through A9 were viewed stereoscopically. The work of Sarna-Wojcicki, et al. (1976) appears quite good. I was able to observe most the features depicted by the authors (agreement indicated by check-marks on plates 1 and 2). Only one of the features indicated by Sarna-Wojckcki, et al. was questionable, in my opinion; I did pick up a possible extension to one of their scarps (these items are noted on plates 1 and 2).

7. Field observations: I examined the Ventura fault on May 5, 1976. I observed a fault (not the main trace) exposed in a road cut along Kalorama Street near Buena Vista Street. This fault is mapped by Sarna-Wojcicki, et al. (1976), as within the San Pedro Formation (early- to mid-Pleistocene) and along the general trend of a scarp. While this fault trace may not be Holocene in age, it does indicate that faulting has occurred during the Pleistocene.

I drove along the main trace, as mapped by Sarna-Wojckcki, et al., from the County Public Works building to the vicinity of the Country Club fault. I was ~~[in my opinion,]~~ consistently able to observe a scarp, 6± meters high in places, as mapped. However, the width of the scarp was usually 30 meters to 100 meters where both the toe and crest of the scarp could be defined. I also visited the site where the trench was

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dug by the County (see plate 1). There was some question in my mind whether other traces might be found a few tens of feet south of the end of the trench (under a parking lot and retaining wall). Generally, the USGS report appears to be quite acceptable for zoning purposes.

8. Conclusions: There is still room for some doubt as to whether the Ventura fault has been active during the Holocene. The gopher bones dated give an approximate age of 6000 y.b.p. to Harmon Fan; however, this must be a minimum age since the soil where the bones were found had to exist, and presumably was buried to a slight depth, for the gophers to burrow in the soil. It is felt by Sarna-Wojckcki, and others, that Harmon Fan a) is probably Holocene in age, b) is cut by the Ventura fault, and c) the Ventura fault has had recurrent movement along it. The case for Holocene faulting and surface deformation is strong, thus the fault should be considered sufficiently active. While the zone of surface faulting and flexure is somewhat wider along the faults, the zone is reasonably well-defined.

9. Recommendations: The Ventura Foothill fault should be zoned as part of the Special Studies Zones Program. One should realize that not all of the traces shown by Sarna-Wojcicki, et al. (1976) are necessarily Holocene; some may be Pleistocene in age.

(4)

10. Investigating geologist's name; date:

Theodore C. Smith

THEODORE C. SMITH
Assistant Geologist
January 7, 1977

Yes
I recommend we zone this fault from Ventura River eastward, the eastern termination to be determined after evaluation of "Country Club" fault. Zoning should be based as closely on Sarna-W, et al and as narrow as possible. Base maps were requested from Dick Brown on 12/16/76, so zoning can begin at your convenience.

1/26/77

Elliott
1/26/77

15'

119°00'

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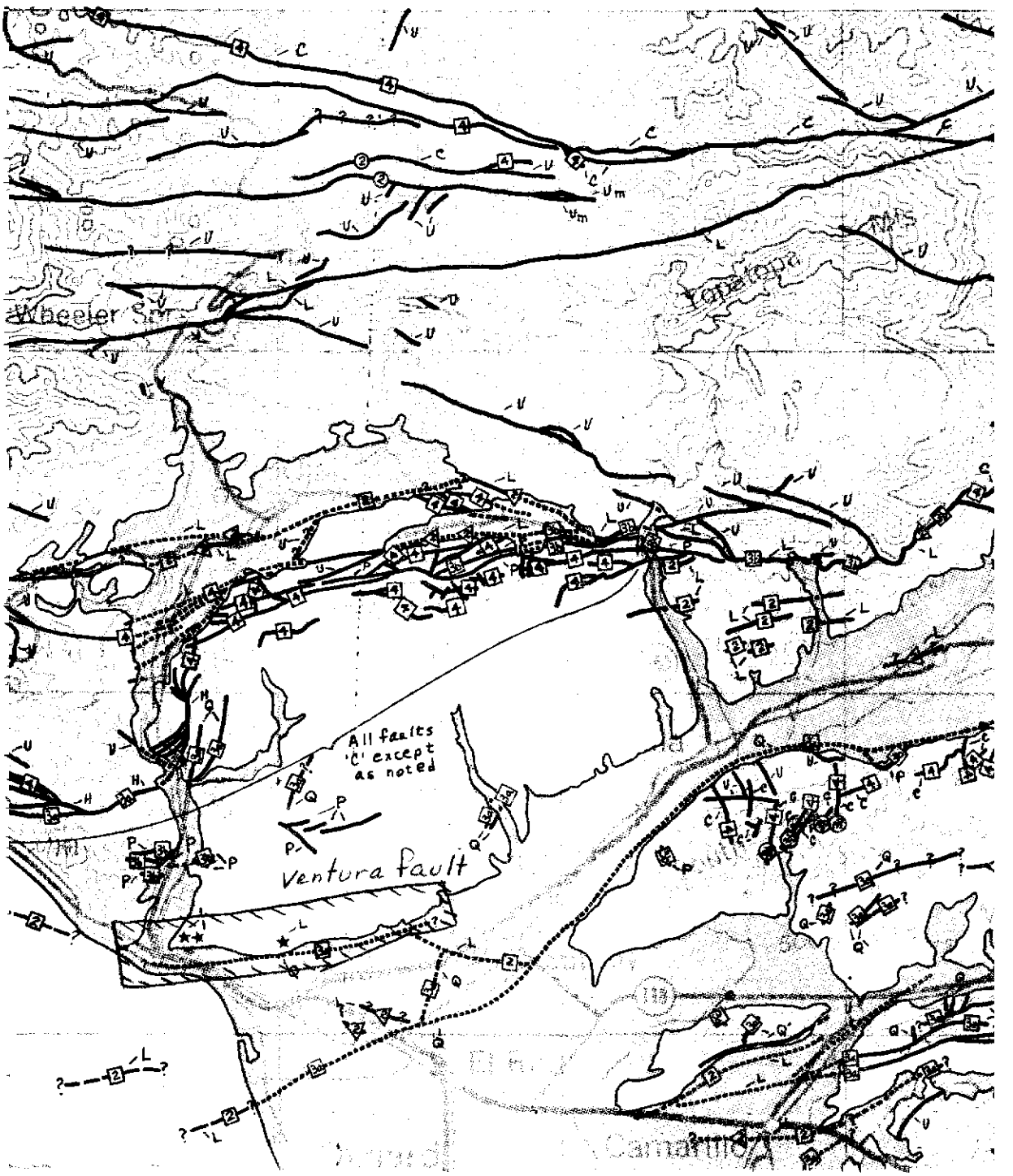
Figure 2 from Ziony, et al., 1974



CONTOUR INTERVAL 20 FEET

Figure 3. From Sarna-Wojcicki, et al., 1976, MF-781.

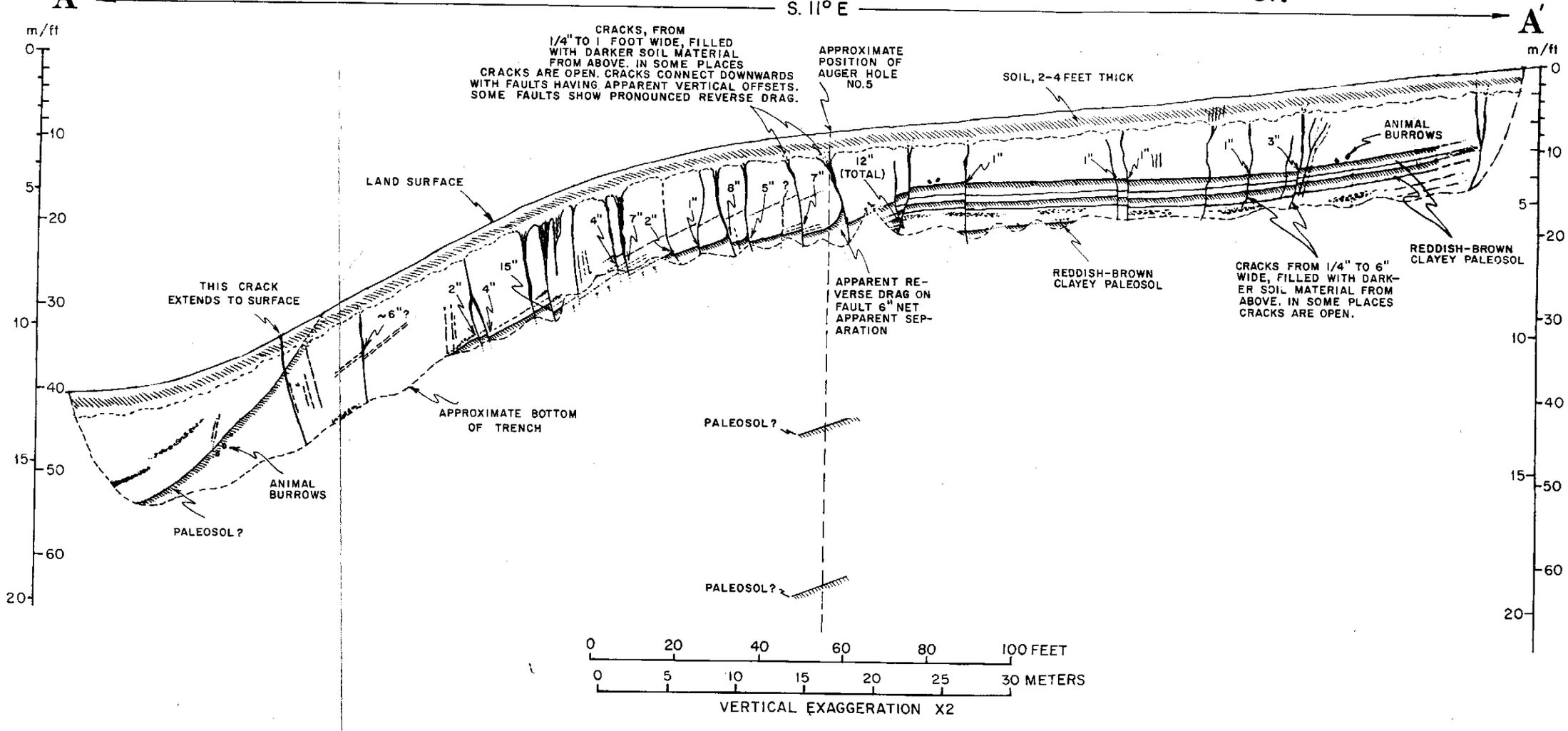



Figure 5. Log of trench A-A' on Ventura County Hospital grounds. Steeply inclined, irregular lines represent cracks, most of which connect downward with faults having measurable apparent vertical displacements. Amounts (inches) of apparent offsets are shown adjacent to the fault traces. Widths of cracks are exaggerated. Dips corrected for vertical exaggeration (2 times). See center of map sheet 2 for location.